(12) UK Patent Application (19) GB (11) 2 332 331 (13) A

(43) Date of A Publication 16.06.1999

(21) Application No 9908441.0

(22) Date of Filing 13.04.1999

(30) Priority Data
(31) 9810772 (32) 19.05.1998 (33) GB

(71) Applicant(s)
Proneta Ltd
(Incorporated in the United Kingdom)
10 Woodlands, HOVE, East Sussex, BN3 6TJ, United Kingdom

(72) Inventor(s)
John Anthony Hother

(74) Agent and/or Address for Service
Frank B Dehn & Co
179 Queen Victoria Street, LONDON, EC4V 4EL, United Kingdom

(51) INT CL^6
H04N 7/18

(52) UK CL (Edition Q)
H4F FAAA FD18R FD27T1 FD30B FD30K FD83B FD83C

(56) Documents Cited
GB 2111795 A GB 2107152 A GB 2102565 A
WO 97/08633 A1
WPI Accession No 87-349260 & DE 3618624

(58) Field of Search
UK CL (Edition Q) H4F FAAA
INT CL^6 G06T 1/00 , H04N 7/18
Online: WPI, EPODOC, JAPIO

(54) Abstract Title

Borehole imaging system

(57) The invention relates to an imaging system or sensor, particularly for use in oil-filled passages such as wells or pipelines, or for passages containing other similar viscous fluids. There is provided a downhole imaging system which operates in a wavelength region outside of the visible band, preferably in the infrared region, to permit penetration of the surrounding fluid medium, e.g. oil. The data may be transmitted from the sensor in a compressed form.

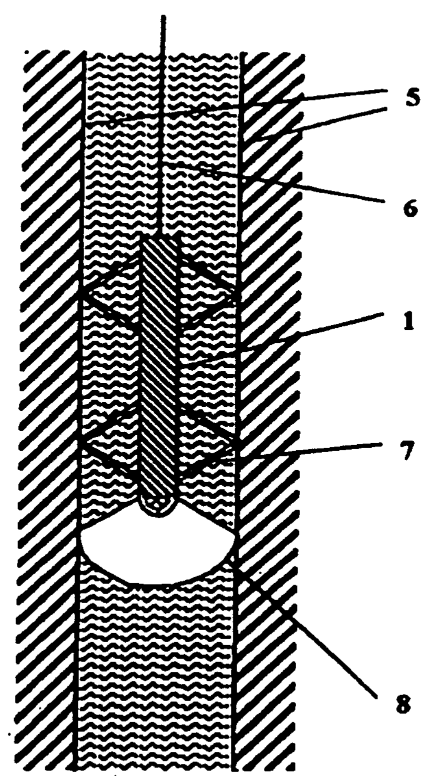


Figure 4

GB 2 332 331 A

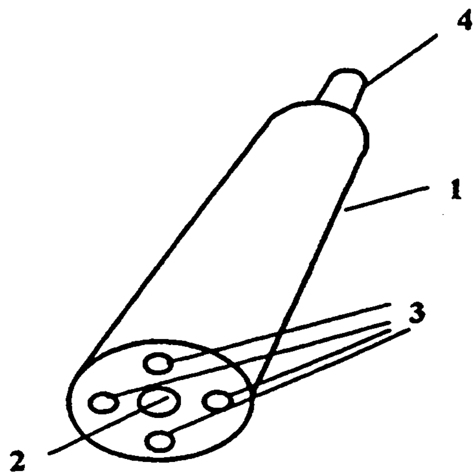


Figure 1

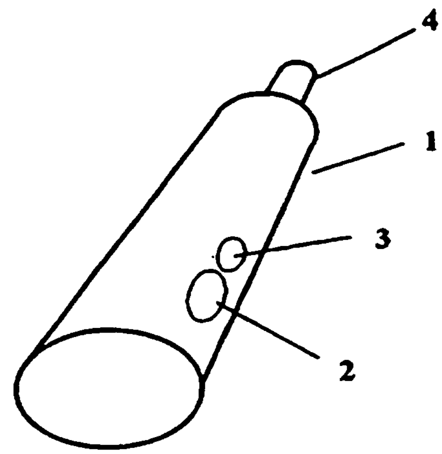


Figure 2

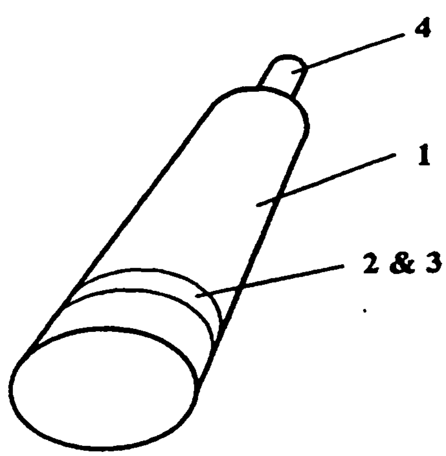


Figure 3

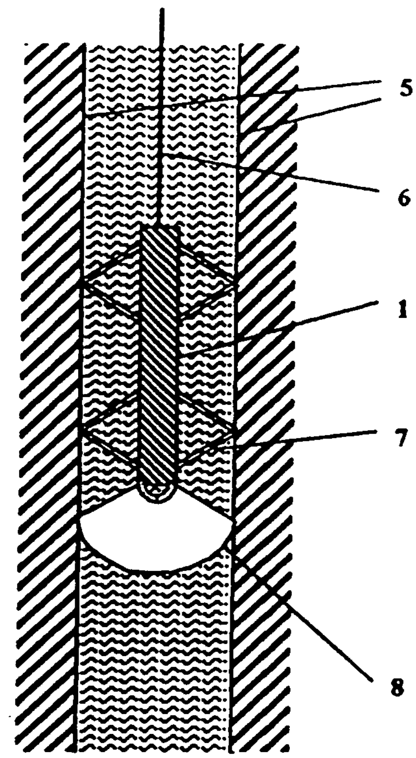


Figure 4

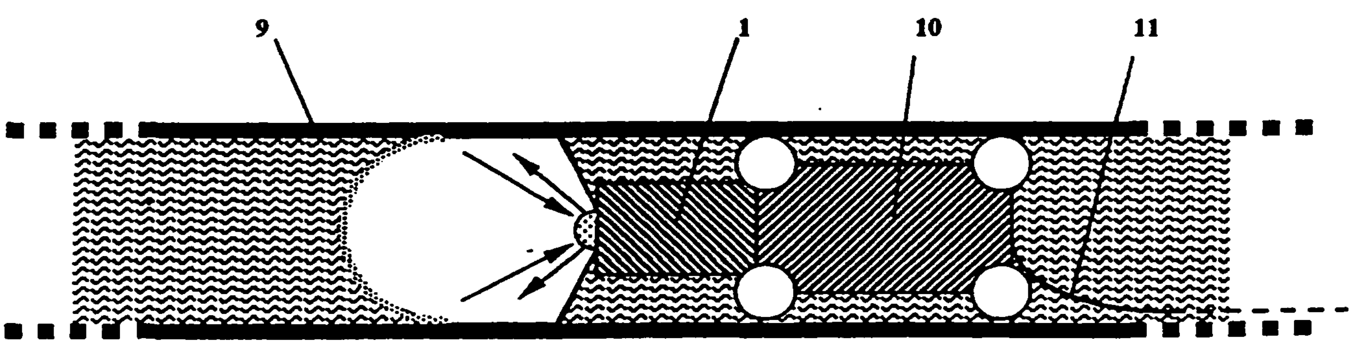


Figure 5

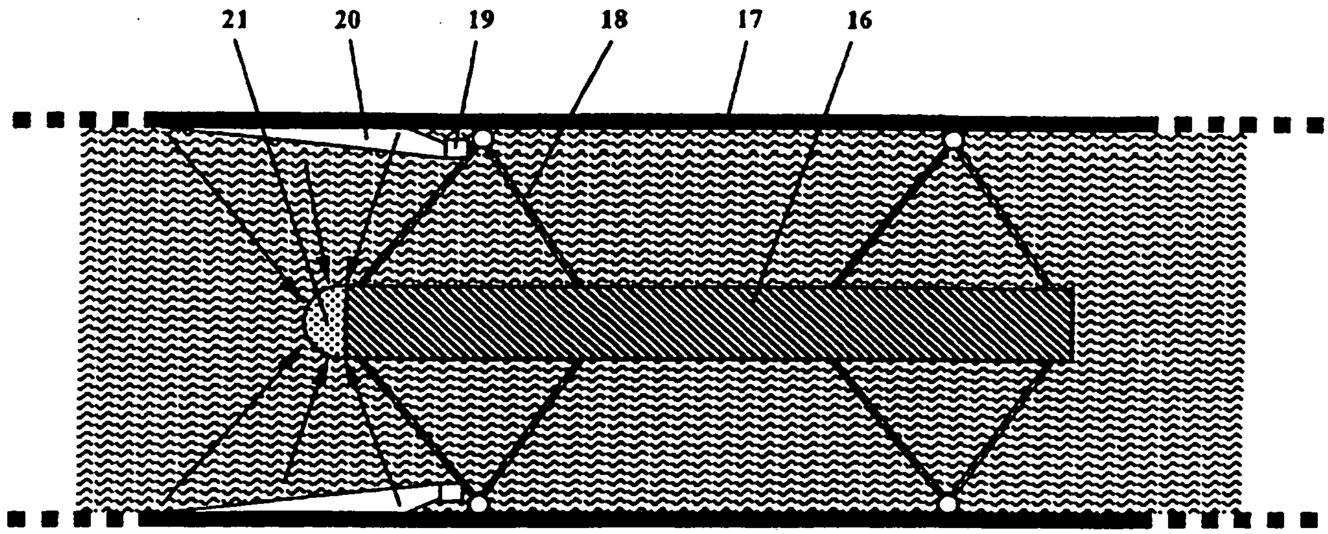


Figure 6

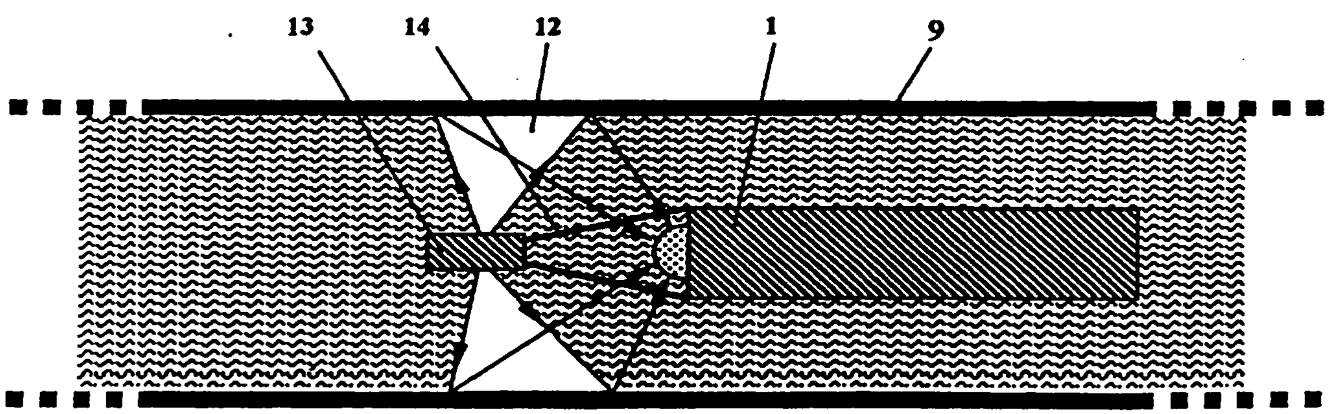


Figure 7

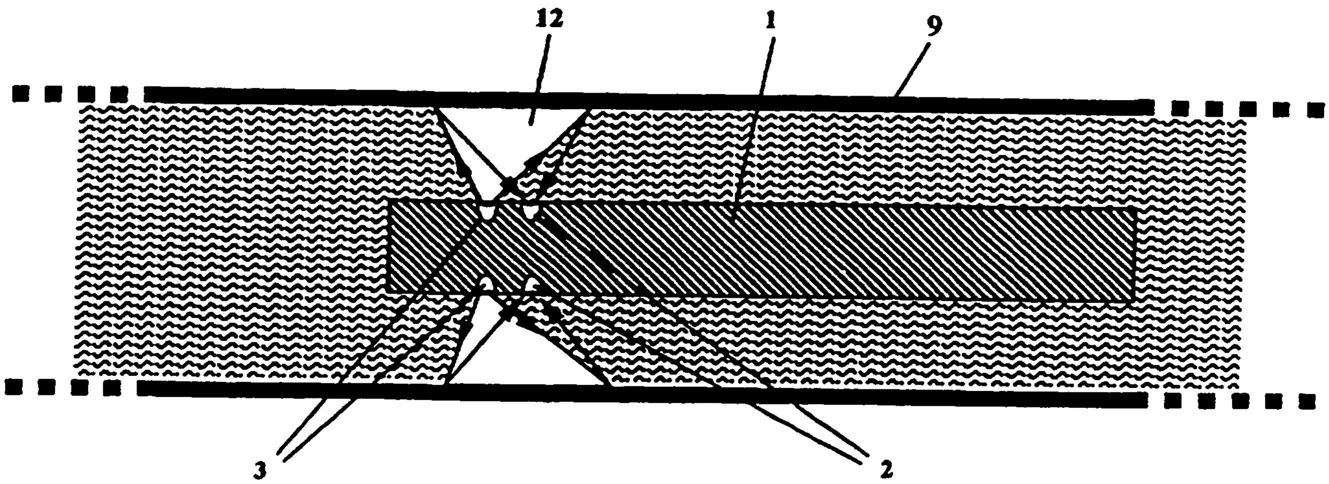


Figure 8

5/9

Figure 9

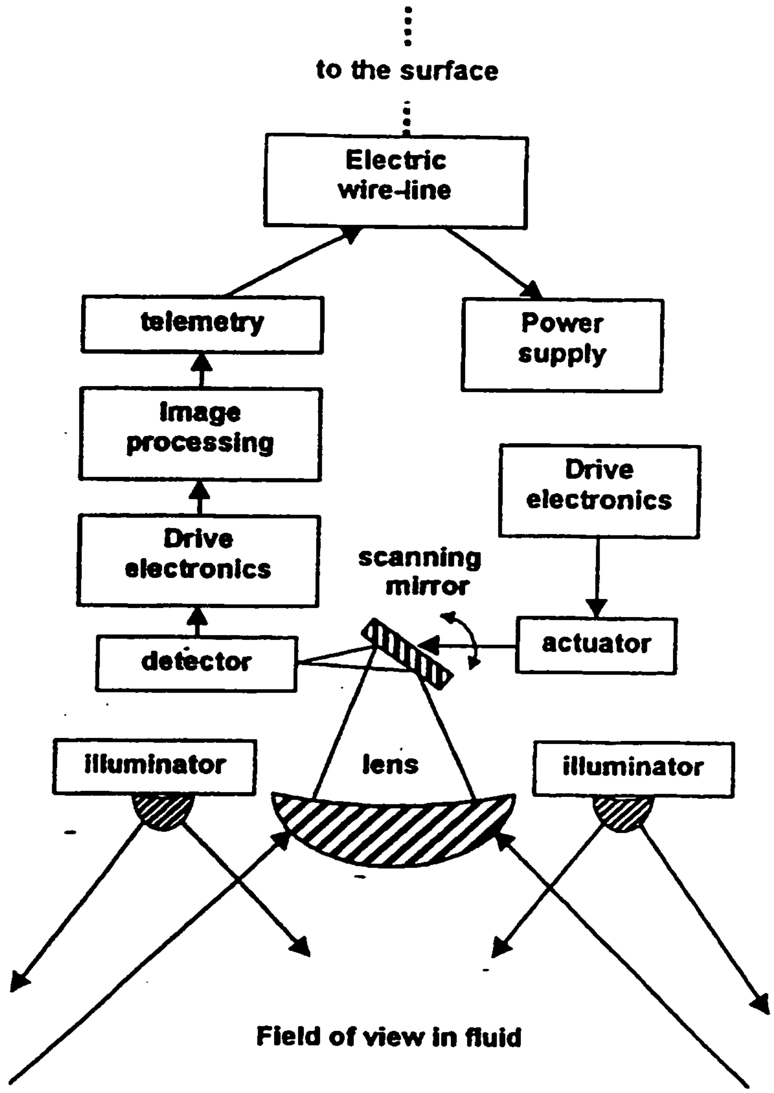
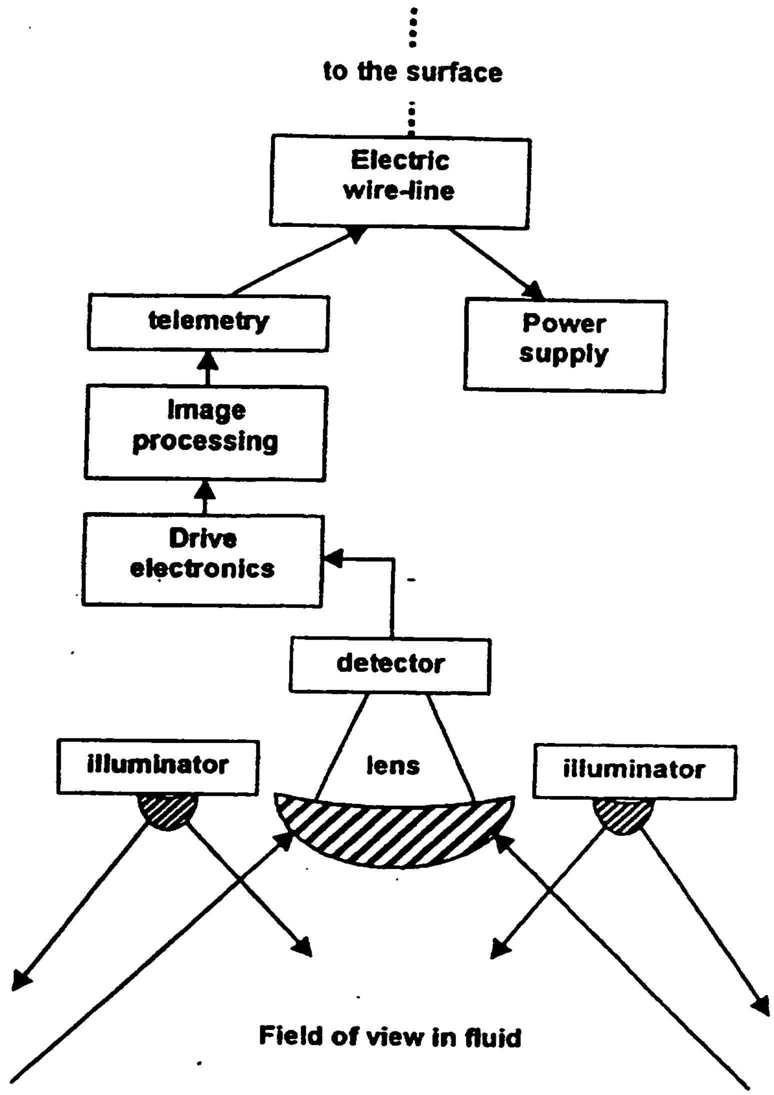

to the surface
Electric wire-line
telemetry
Power supply
Image processing
Drive electronics
Drive electronics
scanning mirror
detector
actuator
illuminator
lens
illuminator
Field of view in fluid

Figure 10


to the surface
Electric wire-line
telemetry
Power supply
Image processing
Drive electronics
detector
illuminator
lens
illuminator
Field of view in fluid

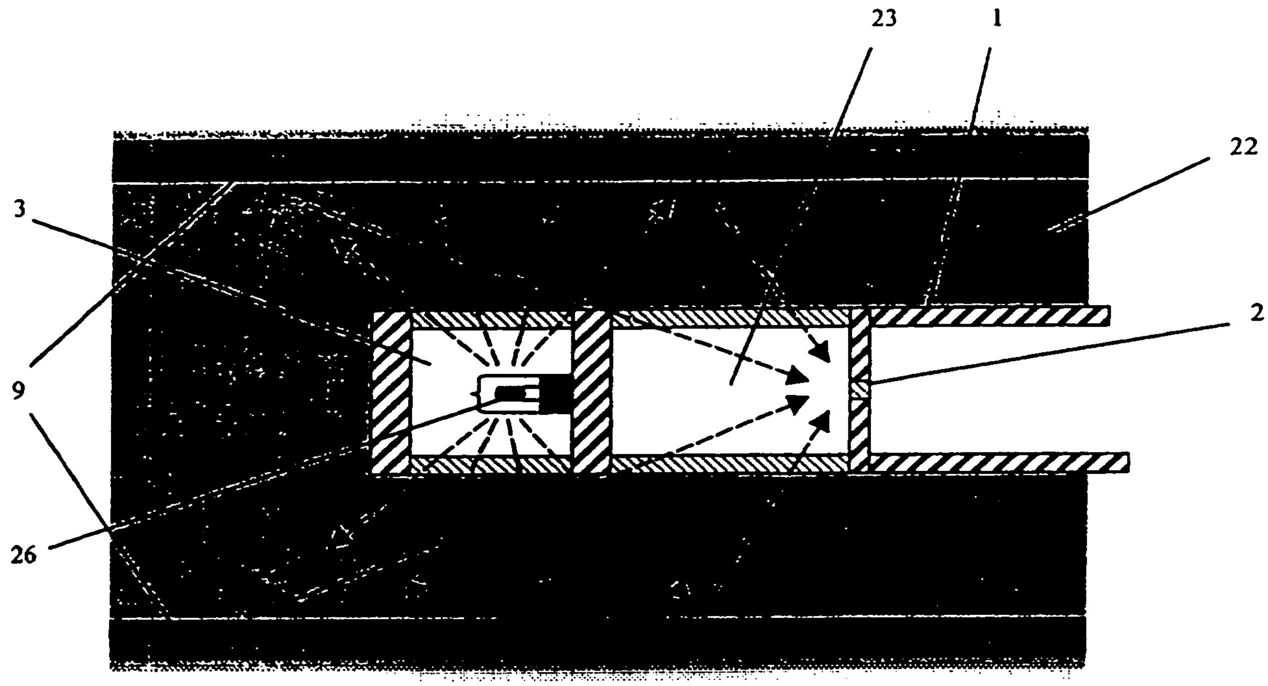


Figure 11

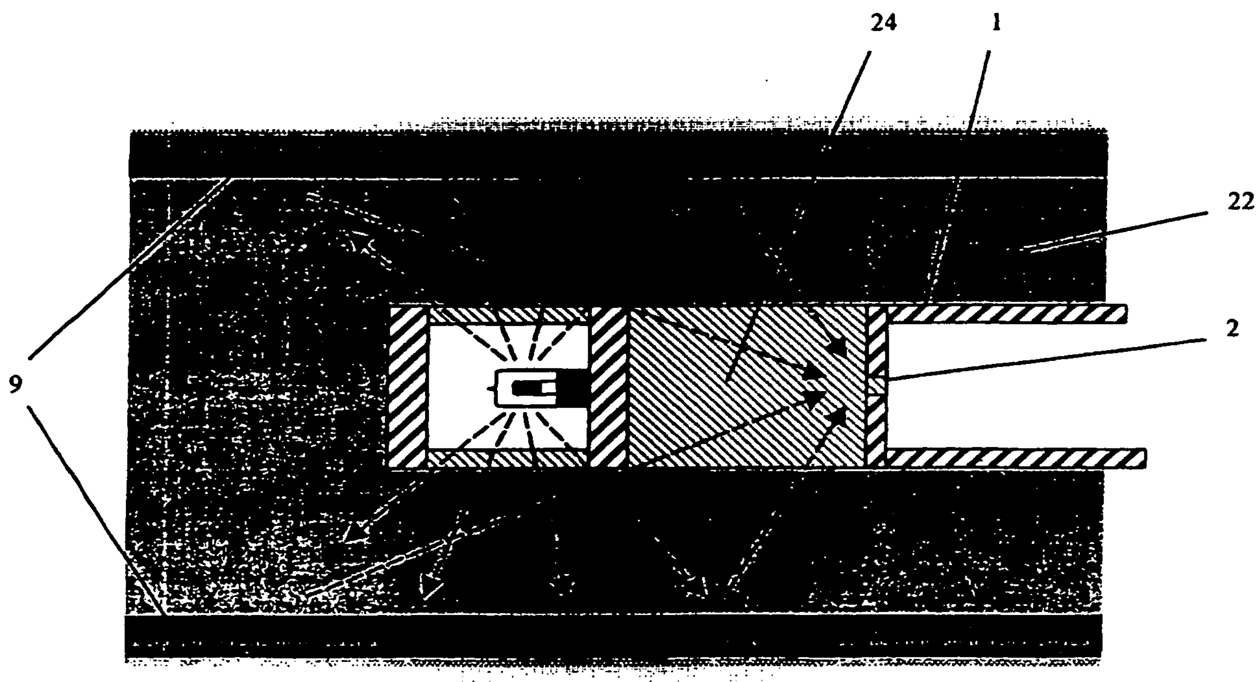


Figure 12

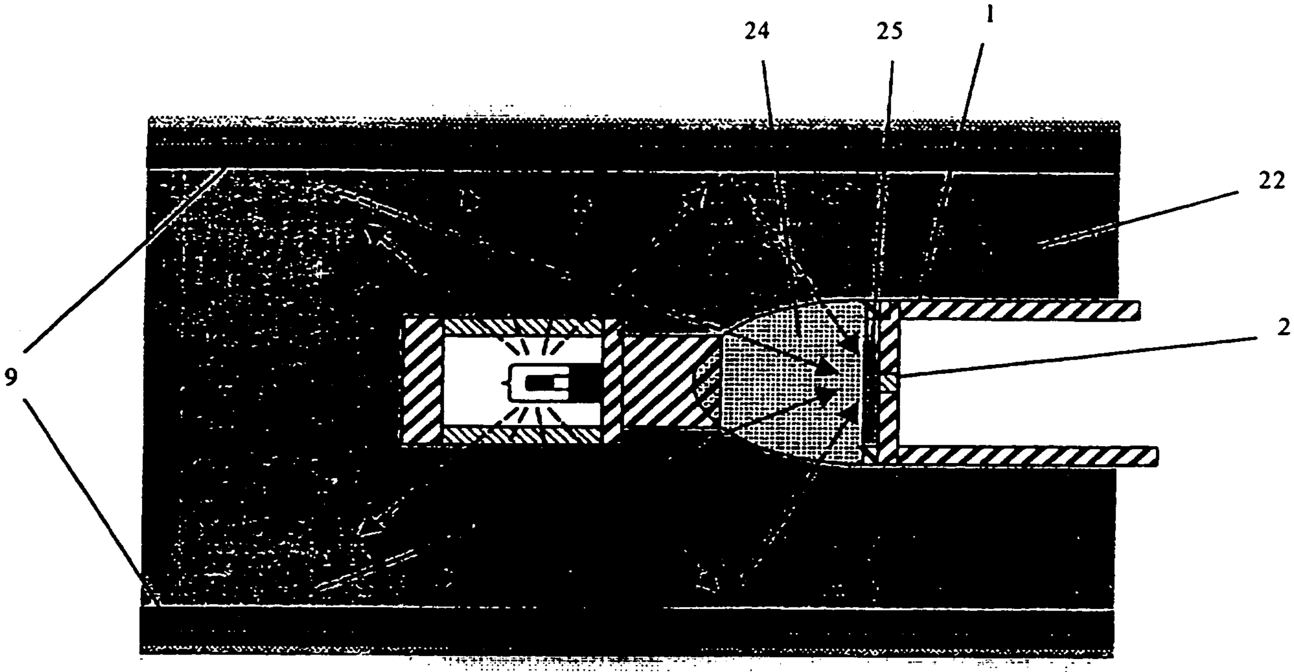


Figure 13

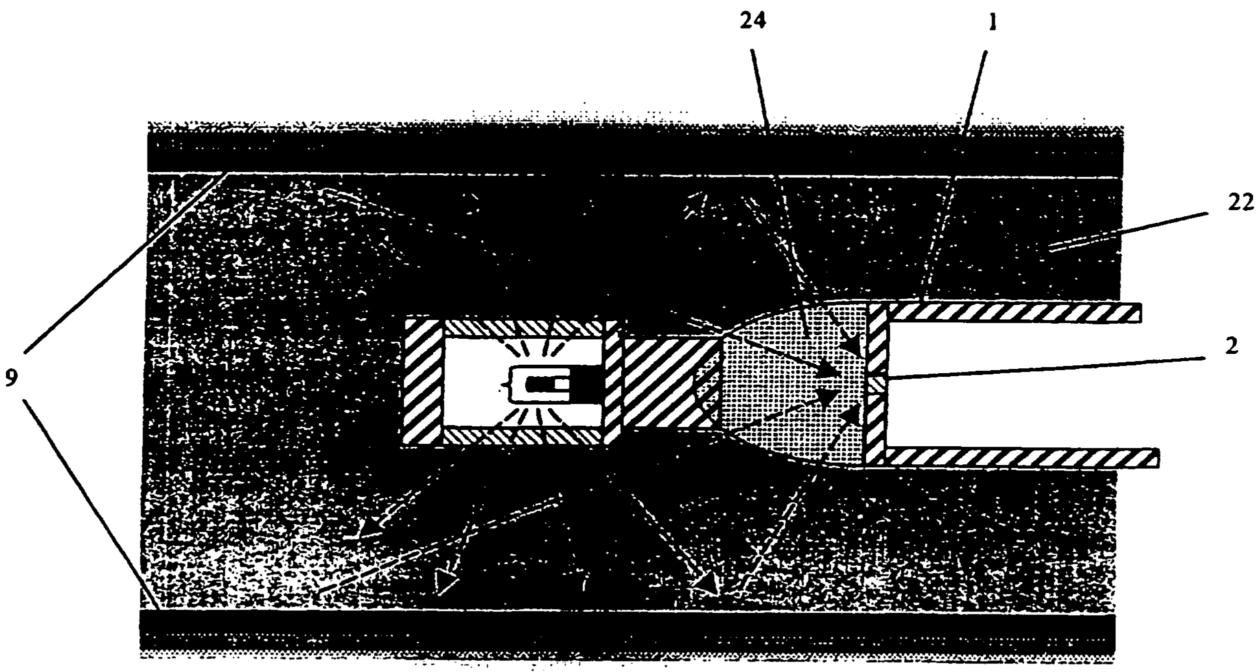


Figure 14

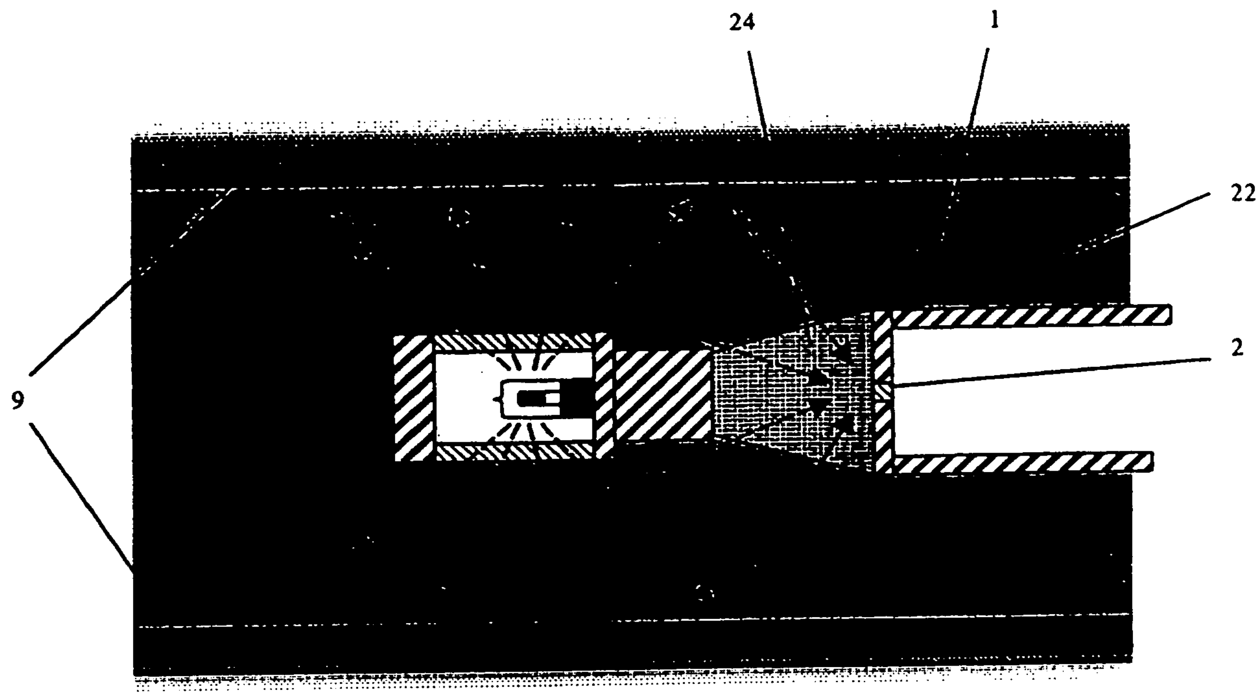


Figure 15

Imaging sensor

The present invention relates to an imaging system or sensor, particularly for use in oil-filled passages such as wells or pipelines, or for passages containing other similar viscous fluids.

Imaging sensors are well-known devices which comprise an optical system, a detector and electronics to provide at a remote point a representation of the image seen by the sensor. An imaging sensor forms the heart of a video camera system which is used in wells or pipelines to provide, outside the hole or pipe, e.g. on a screen or monitor, a visual image of the situation at a point of interest in the hole or pipe.

Early systems for surveying wells used mechanical arrangements for photographing the inside of a well and for providing television images of the inside of the well. Such systems are disclosed, for example, in US 2,632,801; US 2,852,600 and US 2,912,495.

It has been realised that the presence of oil may adversely affect the imaging system.

With imaging sensors operating in the visible light wavelength, problems arise because often the fluid medium in which the system is required to operate exhibits little transmission of visible light and/or contains particles or bubbles which cause significant scattering of visible light. Various attempts have been made to overcome the problems caused by oil, etc. inside the wells.

For example, US 2,912,495 discloses a system wherein oil is cleaned from the lens by hydraulic purging.

WO 94/28440 attempts to deal with this problem by providing a chemical surfactant to the surface of the lens to prevent oil, etc. adhering to the lens and thus

to prevent a remote viewing camera from being obscured by oil and other such fluids.

An article entitled "Fiber Optics Improve Downhole Video" by Philip K. Schultz and Charles Cobb in the Oil and Gas Journal of 11 May 1992, page 46ff. describes the development of downhole imaging systems. In this article, the problem of oil or other opaque fluids adversely affecting the image obtained is discussed. Generally, as discussed in this article, the opaque fluid has to be displaced and this is most commonly done by pumping filtered brine or other transparent mediums, e.g. nitrogen.

The problem of oil or other viscous fluids obscuring the view of the camera is also discussed in an article entitled "Well Preparation - Essential to Successful Video Logging" by J.L. Whittaker and G.D. Linville in SPE 35680.

The problem is also identified in EP-A-0264511 which discloses use of an arrangement of photosensitive elements in an annular array, together with a system of reflecting elements to obtain a high resolution undistorted view of the inner wall of a cavity.

Other systems use particular lighting arrangements in an attempt to improve the image obtained. Some such systems are disclosed, for example, in US 5,402,615 and US 5,663,758.

EP-A-0643198 discloses a video logging system having a remote power source. In this system, the problem of oil, mud, etc. reducing the quality of the image obtained is dealt with by using high intensity lamps.

WO 91/19884 discloses a video logging system also having a remote power source and using optical fibres to conduct the camera signals to the surface for remote viewing.

All of the above systems, whilst identifying the fact that down-hole images are obscured by oil, mud,

etc. all attempt to deal with this problem by using additional mechanical means or higher power lamps, etc. This all increases the cost, complexity and weight of the imaging system.

The aim of the present invention is to overcome the problems identified above and to enable clear images to be provided to a remote point outside of the well, without the need for additional complex and expensive apparatus.

Accordingly, in one aspect the present invention provides a downhole imaging system which operates in a wavelength region outside of the visible band, preferably in the infrared region, to permit penetration of the surrounding fluid medium, e.g. oil.

In a preferred embodiment, the present invention provides a downhole imaging sensor comprising illuminating means, optical transmission means and optical detector means operating in the infrared wavelength region, and further comprising circuitry to perform image processing, based on the signals detected by the optical detector means. The image processing circuitry preferably compresses the received signals and transmits them to a remote plane.

The illuminating means, the optical transmission and detector means and the electronic circuitry are preferably all arranged in a protective housing for protection from the operating environment.

In accordance with a second aspect, the invention comprises a method of providing images of the interior of a cavity, comprising transmitting and detecting infrared radiation inside the cavity and providing an image at a remote point according to the detected radiation.

The inventor has discovered that because the sensor operates in this preferably infrared wavelength region, it can capture an image of the scene despite the presence of oil or other fluids which do not transmit

sufficient visible light to form a useful image.

The sensor may be provided with means for controlling its movement and position inside the pipe or well. Various means may be used, e.g. a slick wireline, an electric wireline or a fibre-optic wireline. Also, or alternatively the sensor may be attached to a tractor.

Similar means may also be provided to allow power, and/or control information to be transmitted to the sensor, and/or to transmit image and status information from the sensor.

The image processing circuitry may carry out various processing functions to derive useful information from the sensor signals. For example, the processor may determine the volumes of bubbles of different fluids in the surrounding medium and the velocities of those bubble from successive images. The processor may also calculate the flow rates of different fluids in the surrounding medium and record and/or report or display the information.

The image processing circuitry may also locate scattering particles in the surrounding medium by comparing successive image frames and distinguishing the particles by their velocity relative to the sensor. These particles can then be removed from the image.

A preferred embodiment of the present invention will now be described, by way of example only with reference to the accompanying drawings.

Figure 1 is a perspective view of the general arrangement of the main externally visible parts of an imaging sensor according to the invention, in an axial-view configuration.

Figure 2 is a perspective view of the general arrangement of the main externally visible parts of the imaging sensor of Figure 1, in a radial-view configuration.

Figure 3 is a perspective view of the general

arrangement of the main externally visible parts of the imaging sensor of Figure 1, in a peripheral-view configuration.

Figure 4 is a partial cross-sectional side view of the imaging sensor in a well.

Figure 5 is a partial cross-sectional side view of the imaging sensor in a pipeline.

Figure 6 is a partial cross-sectional side view of one possible configuration of the illumination and the sensor's field of view.

Figure 7 is a partial cross-sectional side view of another possible configuration of the illumination and the sensor's field of view.

Figure 8 is a partial cross-sectional side view of another possible configuration of the illumination and the sensor's field of view.

Figure 9 is a schematic block diagram of the constituent parts of the imaging sensor using a linear detector array.

Figure 10 is a schematic block diagram of the constituent parts of the imaging sensor using a two-dimensional (matrix) detector array.

Figures 11 to 15 show alternative embodiments of the arrangement of the illumination means.

As illustrated in the drawings, the invention is particularly intended for use in well logging, shown in Figure 2, for examining the interior of a well, or in pipeline inspection, shown in Figure 3, for examining the interior of a pipe. The novel aspect is that it operates in the infrared wavelength range of approximately 0.8 micrometres to approximately 2.0 micrometres in order to penetrate the surrounding fluid medium (oil).

The preferred imaging sensor consists of a housing 1 containing the working parts, with the optical assembly or lens 2 at one end of the housing, shown in Figure 1, at the side of the housing as shown in Figure

2, or around the periphery of the housing as shown in Figure 3. The housing 1 also contains the detector and electronics and is releasably secured to the cable, wireline, coiled tubing or well tractor by an attachment 4.

The illuminator(s) 3, of which there may be one or several incorporated, are mounted so as to illuminate the field of view of the optical assembly or lens 2. They may be at one end of the housing as shown in Figure 1, at the side of the housing as shown in Figure 2, around the periphery of the housing as shown in Figure 3 and Figure 8, or mounted remotely from the housing as shown in Figure 6 and Figure 7.

Figures 11 to 15 show further possible arrangements of the illuminator(s) relative to the lens. In Figure 11, the illuminator (3) is mounted on a gas-filled or liquid-filled chamber on the end of the sensor housing. In Figure 12 the illuminator is mounted on a solid transparent component of cylindrical form on the end of the sensor housing. In Figure 13 the illuminator is mounted on a solid transparent component which is separated from the end of the sensor housing by an oil-filled chamber. In Figure 14 the illuminator is mounted on a solid transparent component of spherical, elliptical or parabolic form on the end of the sensor housing. In Figure 15 the illuminator is mounted on a solid transparent component of conical form on the end of the sensor housing. These alternative embodiments will be further described later.

The detector may, for example, take the form of:

a two-dimensional detecting array;

or a linear detecting array with a scanning device to scan the image across the array;

or a single-point detector with a scanning device to scan the image across the single-point detector.

In a preferred embodiment, the detector is a vacuum tube device which is scanned electronically and has a

sensitive front faceplate upon which the image is focussed by the lens.

In well logging as shown in Figure 4, the imaging sensor is attached to a wire-line 6 going to the surface, which provides mechanical control of the movement and positioning of the sensor in the well. The attachment 4 may also provide the means of connecting electrical power to the sensor, and/or control signals to the sensor, and/or image signals from the sensor. Means may be provided to position the sensor radially 7, to centralise the field of view 8 in the bore 5, or to offset the field of view in the bore to concentrate on a particular point of interest.

In pipeline inspection as shown in Figure 5, the sensor housing 1 is releasably attached to a tractor, which provides mechanical control of the movement and positioning of the sensor in the well. The attachment may also provide the means of connecting electrical power to the sensor, and/or control signals to the sensor, and/or image signals from the sensor. A harness 11 incorporating electrical cables, and pneumatic or hydraulic pipes, provides the means for supplying power to the tractor and sensor, controlling signals to them, and image signals back to the external display and recording facility. Means may be provided to position the sensor radially as in Figure 4, or the tractor may provide this facility. This provides for centralising the field of view 8 in the bore 9, or offsetting the field of view in the pipe to concentrate on a particular point of interest.

In order to minimise the losses due to absorption of the illumination by the surrounding fluid medium, the illuminators 3 may be mounted external to the housing 1 as shown in Figure 6. In this example, the illuminators 3 are mounted on the spider assembly 7 used for radial control or centralising of the housing 1 in the bore 9. Electrical cables run through the members of the spider

assembly 7 from the sensor electronics to supply the power for the illuminators. The beams 12 from the illuminators are orientated so as to illuminate the field of view of the sensor's optical assembly or lens 2.

An alternative external mounting arrangement of the illuminators is shown in Figure 7, in which a pod 13 accommodating the illuminators is held some distance away from the sensor housing 1 by structural members 14 inside which run the electrical cables from the sensor electronics to supply the power for the illuminators. The beams 12 from the illuminators are orientated so as to illuminate the field of view of the sensor's optical assembly or lens 2.

The illuminator and optical part of the imaging sensor can be constructed in various alternative configurations. Figures 11 to 15 show the imaging sensor housing 1 with the lens 2 in a well, pipe or vessel 9 containing a fluid 22 such as crude oil that is opaque to visible light.

Mounting the illuminator away from the imaging sensor housing by a spider of structural members, as shown in Figure 7, results in partial obscuration of the imaging sensor's field of view by those structural members. This problem can be minimised by configuring the optical assembly so that it can support the illuminator, dispensing with the need for any other structural members, as shown in several different forms in Figures 11 to 15.

Some obscuration will still be caused by the electrical wires providing the power from the imaging sensor body 1 to the illuminator 3, but these can be very much thinner than structural members, so the obscuration is very much reduced.

This arrangement, in the various configurations shown in Figures 11 to 15, also provides the advantage of reducing the path length of the rays, shown as dashed lines, in the highly absorbing oil 22 in which the imaging sensor is operating. Instead, a significant part of the path length is within highly transmissive gas in chamber 23 ahead of the lens 2. The walls of chamber 23 are of transparent material at the operating wavelengths such as acrylic, fused silica or glass, or have windows of such a material. The benefit is a greater image signal, giving a better picture and allowing the imaging sensor to be used in more highly absorbing oils.

Figure 12 shows the gas-filled chamber replaced by a solid component 24 made of a material which is highly transmissive at the operating wavelengths such as acrylic, fused silica or glass. That component 24 may be take any of a variety of shapes, to provide differing lens effects and achieve the required performance. For example, Figure 12 shows it as a cylinder, figure 15 shows a cone, and Figures 13 and 14 show a dome which may be of spherical, parabolic or elliptical form.

Figure 13 shows how the component 24 may be separated from the imaging sensor body by a chamber 25, which is open to the surrounding oil. This allows the component 24 to experience an equal pressure from the surrounding fluid on all its surfaces, simplifying its design. The chamber 25 is small, to minimise the path length of the rays in the oil. In this configuration, lens 2 is required to seal the imaging sensor housing from the surrounding oil 22. Because that oil may be at very high pressure, lens 2 is replaced or augmented by a window, transparent at the wavelength of interest, with a pressure seal. This arrangement can be used with any of the shapes for the component 24: a cylinder, a cone,

or a dome of spherical, elliptical or parabolic form.

In any form of the imaging sensor, the source of illumination may be any device or combination of devices that provide sufficient output at the desired operating wavelengths, such as lasers, light-emitting solid-state diodes, incandescent lamps and discharge lamps. In figures 11 to 15 inclusive, an incandescent lamp 26 is shown as an example.

In figure 11, the chamber 24 may be liquid-filled rather than gas-filled, with a means of equalising the pressure inside with that of the surrounding oil, so that the chamber walls may be thinner and the chamber easier to produce. The liquid is chosen to be transparent at the operating wavelengths, such as water or light oil. The lens 2 is then augmented or replaced by a pressure-tight transparent window. Such a liquid-filled chamber may be cylindrical, as shown in Figure 11, or may take any of a variety of shapes, to provide differing lens effects and achieve the required performance, such as a cone, or a dome which may be of spherical, parabolic or elliptical form.

CLAIMS

1. A downhole imaging system which operates in a wavelength region outside of the visible band to permit penetration of the surrounding fluid medium.

2. A downhole imaging sensor as claimed in Claim 1, comprising illuminating means, optical transmission means and optical detector means operating in the infrared wavelength region, and further comprising circuitry to perform image processing, based on the signals detected by the optical detector means.

3. A downhole imaging sensor as claimed in claim 2, wherein the image processing circuitry comprises means to compress the received signals and means for transmitting them to a remote plane.

4. A downhole imaging sensor as claimed in claim 2 or 3, wherein the optical transmission and detector means and the image processing circuitry are arranged in a protective housing for protection from the operating environment.

5. A downhole imaging sensor as claimed in any of claims 2 to 4, wherein the detector means is provided with means for controlling its movement and position inside a pipe or well.

6. A downhole imaging sensor as claimed in any of claims 2 to 5, further comprising means for transmitting power and/or control information to be transmitted to the detector means.

7. A downhole imaging sensor as claimed in any of claims 2 to 6, further comprising means for transmitting image and status information from the detector means.

8. A downhole imaging sensor as claimed in any of claims 2 to 7, wherein the detector means is a two-dimensional array of pixels.

9. A downhole imaging sensor as claimed in any of claims 2 to 7, wherein the detector means is a linear array of pixels with a scanning device to scan the image across the array.

10. A downhole imaging sensor as claimed in any of claims 2 to 7, wherein the detector means is a single point detector with a scanning device to scan the image across the detector.

11. A downhole imaging sensor as claimed in any of claims 2 to 7, wherein the detector means is an electronically scanned vacuum tube with an infrared-sensitive coating upon which the image is formed.

12. A downhole imaging sensor as claimed in claim 4 or any claim dependent thereon, wherein said illuminating means is mounted on a gas or fluid filled chamber provided on the housing such that said illuminating means is spaced from and in front of said detector means.

13. A downhole imaging sensor as claimed in claim 4 or any claim dependent thereon, wherein said illuminating means is mounted on a solid transparent member provided on the housing such that said illuminating means is spaced from and in front of said detector means.

14. A downhole imaging sensor as claimed in claim 13, wherein said solid transparent member is cylindrical.

15. A downhole imaging sensor as claimed in claim 13, wherein said solid transparent member is spherical,

elliptical or parabolic.

16. A downhole imaging sensor as claimed in claim 13, wherein said solid transparent member is conical.

17. A method of providing images of the interior of a cavity, comprising transmitting and detecting infrared radiation inside the cavity and providing an image at a remote point according to the detected radiation.

18. A method as claimed in Claim 17 wherein the detected infrared radiation is transmitted in the form of compressed signals to a remote plane.

19. A method as claimed in claim 17 or 18, comprising the steps of determining the volumes of bubbles of different fluids in the surrounding medium and the velocities of those bubble from successive images.

20. A method as claimed in claim 17, 18 or 19 further comprising calculating the flow rates of different fluids in the surrounding medium and recording and/or reporting or displaying the information.

21. A method as claimed in claim 17, 18, 19 or 20 further comprising locating scattering particles in the surrounding medium by comparing successive image frames and distinguishing the particles by their velocity relative to the detector means.

22. A downhole imaging sensor substantially as hereinbefore described with reference to the attached drawings.

The Patent Office

14

INVESTOR IN PEOPLE

Application No: GB 9908441.0
Claims searched: All

Examiner: Joe McCann
Date of search: 4 May 1999

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): H4F(FAAA)

Int Cl (Ed.6): H04N(7/18);G06T(1/00)

Other: Online: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X,Y	GB 2111795A	(ROCKWELL INTERNATIONAL) - see page 3 lines 80 to 90	X:1,2,4-11, 13-17 Y:3,18
X,Y	GB 2107152A	(ROCKWELL INTERNATIONAL) - see page 4 lines 1 to 6	X:1,2,4-11, 13-17 Y:3,18
X,Y	GB 2102565A	(DRAFTRULE LTD) - see abstract	X:1,2,4-11, 13-17 Y:3,18
Y	WO97/08633A1	(INTEGRATED COMPUTER UTILITIES) - see abstract	3,18
X,Y	WPI Accession No 87-349260 & DE 3618624(B.BRANDES),10.12.87 - see abstract		X:1,2,4-11,13-17 Y:3,18

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		